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Cashew Shells:

from Waste to Energy & Profit

TechnoServe has a proven commitment to building competitive and inclusive cashew industries throughout Africa by building the capacity of actors along the value chain.

An important part of TechnoServe's strategy is to innovate new ways to create value. Cashew shells are a readily available – albeit under-utilized – opportunity to bolster the profitability and competitiveness of the entire cashew value chain while growing environmental stewardship and helping to curb climate change.

Our vision for cashew shells is a circular business model of green growth.

Cashew shells in Africa today are largely treated as a waste product of cashew kernel processing and are disposed of at an economic and environmental cost. The shells, however, can be used to generate energy, thereby providing three layers of impact that increase cashew sector profitability and competitiveness in an inclusive and sustainable way.

TechnoServe
Business Solutions to Poverty

GREEN GROWTH MODEL:
Co-Generation Heat and Power Plant Fueled by Shells

A. The Energy Challenge for African Cashew Processors

Unreliable and expensive energy is a large burden for African cashew processors. Power outages in sub-Saharan Africa occur on average 1 in 4 days of the year, and voltage fluctuations are frequent. These disruptions limit efficiency: the World Bank estimates that African enterprises lose ~6% of annual turnover due to electrical outages. Despite its unreliability, energy in the region is extremely expensive. According to the African Development Bank, electricity costs three times more in Africa than in comparable developing regions, due to both the high cost of power sourced from the grid and reliance on expensive back-up generators to compensate for frequent grid outages. High energy costs and frequent outages and fluctuations thus limit African cashew processor competitiveness. Finding a solution to these challenges is critical to the success of the entire sector. The benefits of a strong processing sector extend beyond processors themselves, e.g., by providing a steady market for cashew farmers and formal jobs and wages for employees in rural areas. Improving access to reliable, affordable energy thus builds the competitiveness of the cashew value chain, and strengthens capacity of actors *across* the value chain.

> Cashew shells today are an economic burden for processors, and pose significant environmental risks to surrounding communities.

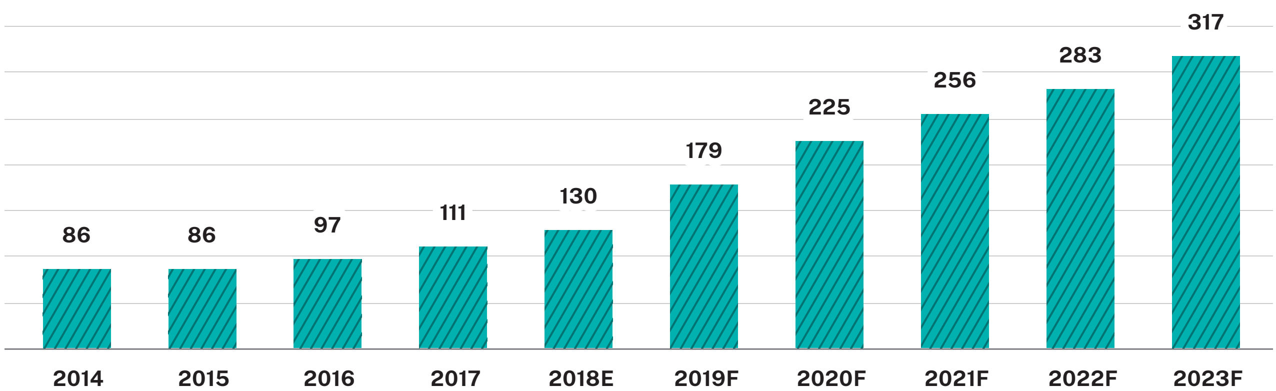
B. & C. Cashew Shells:
Economic and Environmental Burden

The cashew shell accounts for 70% of raw cashew nut (RCN) weight. The shell contains cashew nut shell liquid (CNSL), which accounts for 0.2 kg per kg of RCN, and the shell's dried husk, which accounts for 0.5 kg per kg of RCN. Approximately 110K MT of shell were generated from cashew kernel processing in Africa in 2017. After extracting cashew kernels from RCN, processors typically discard the shells as a waste product. While small volumes of shells are burned to generate steam needed in kernel processing, the majority of shells (~75-95%) are disposed of.

Shells are commonly disposed of in one of two ways: shells are either dumped in designated waste sites offsite from the factory or burnt in open pits at the factory site or in neighboring areas. Both methods of shell disposal come at an economic cost to kernel processors and environmental cost to surrounding communities. In Cote d'Ivoire, kernel processors pay disposal costs of ~2K FCFA (~3 USD) per MT of shell. Moreover, once dumped, cashew shells have adverse environmental effects. As shells decompose, they release methane and carbon dioxide into the atmosphere (0.1 tCO2eq per MT of shell), and CNSL leaks out of the shells and into the ground, compromising soil fertility and polluting surface water. The alternative solution to dumping—burning the discarded shells—not only creates added energy costs for processors, but also generates carbon emissions that fuel climate change.

While some processors valorize shells by extracting CNSL for sale to export markets, the remaining de-oiled shell "cakes" still pose an environmental burden. TechnoServe has supported kernel processors in Benin and Mozambique to install CNSL processing operations. CNSL is a viscous and caustic substance that can be used in the production of industrial inputs (e.g., resin, paints, varnishes, and brake fluid) as a bio-alternative to chemicals. CNSL has been shown to improve processor competitiveness, with a direct impact of ~9% on a processor's bottom line. However, shell disposal remains an inconvenience and environmental burden: CNSL processing yields a de-oiled shell cake that must be disposed of in the same way as the raw shells. Moreover, the majority of African processors are not equipped with CNSL processing equipment, and so still face the full economic burden of shell disposal.

VOLUME OF CASHEW SHELL WASTE IN AFRICA (000s OF MT)



D. **Cashew Shells:** A Solution to the Energy Challenge of Processors

> Though treated as a waste product of kernel processing, cashew shells are an unexploited source of energy.

Cashew shells have very high energy potential, and can provide energy in several different ways. First, “raw” shells (i.e. shells with CNSL) can be used directly as biofuel- combusted or gasified to generate energy (e.g., as currently burned by processors to generate steam for kernel processing). Alternatively, processing the raw shells into CNSL and de-oiled shell cakes yields cleaner biofuels than the raw shells themselves. CNSL has a comparable quality and heat content to light fuel oil, and calorific volume to petroleum oil. While de-oiled shell cakes have slightly less energy potential than raw shells due to the absence of CNSL, they provide cleaner energy: due to lower ash content, de-oiled shells release fewer greenhouse gas emissions when burnt. De-oiled shell cake is considered one of the best biofuels, with a very high calorific value similar to that of lignite coal (~4700 kcal/kg), and 90-95% the heating value of wood.

CURRENT EFFORTS TO USE SHELLS FOR ENERGY LACK SCALE AND SUSTAINABILITY

While there are existing initiatives in Africa to generate energy and energy products from cashew shells, their viability and financial sustainability have not yet been proven. As these projects are largely still in the research and development phase, the technology remains artisanal and the impact limited. For example, shells can be carbonized to produce charcoal through a charcoal retort, or gasified to generate power. Current gasification solutions, however, generate only 50-1000 kW of energy. And while CNSL can be used locally as a biofuel, it is largely exported for use in industrial applications. Lastly, existing initiatives are largely reliant on subsidies. Without a clear business case, these technologies have difficulty attracting investment needed to scale.

Kernel processors in Asia, however, currently process large volumes of shells into biofuel, thereby generating energy at scale. For example, India uses cashew shells as an additional revenue source to meet overhead expenditure, rather than disposing them as a waste product of kernel processing. India has power plants fueled by de-oiled cashew shell cake that support the country’s power needs. These power plants generate energy at large scale, ranging in capacity from 1-6 MW.

TECHNOSERVE’S MODEL CAN CREATE ENERGY FROM CASHEW SHELLS ON AN INDUSTRIAL SCALE

TechnoServe conducted a benchmarking study to evaluate the opportunity for industrial power generation using cashew shells in Africa. Learning from technology used by Asian processors, TechnoServe selected and designed an ideal mix of technologies fit for the African context.

> While there have been small-scale initiatives in Africa to generate energy from cashew shells, this proposed system is the first with potential to generate power at scale.

TechnoServe designed models for a steam and electricity power plants with capacities ranging from 0.5-3 MW of energy, using de-oiled cashew shell cake as biofuel.

TechnoServe has identified a co-generation heat and power (CHP) plant that uses de-oiled shell cake as the most efficient system to produce energy from cashew shells. Manufacturing plants typically source energy and heat separately: energy originates from an external, central power plant, and steam is generated on-site using factory equipment. A CHP system has two advantages over the conventional sourcing process. First, the co-generation of electricity and steam increases the system's overall energy efficiency by almost 2x. The conventional method of separate steam and power generation is highly inefficient: more than half of energy produced is wasted. To produce electricity, water is heated up and transformed into steam, which is used to power a turbine. Afterwards, the heat is wasted, leading to a thermal and electric efficiency of 45%. In a CHP system, however, heat is recaptured and used for industrial applications, thereby increasing efficiency to ~85%. Second, a CHP system negates energy losses due to transmission and distribution from the power plant to the energy's end use (typically 7%). By producing and consuming power in a single site, the CHP system does not suffer losses from transmitting energy across large distances.

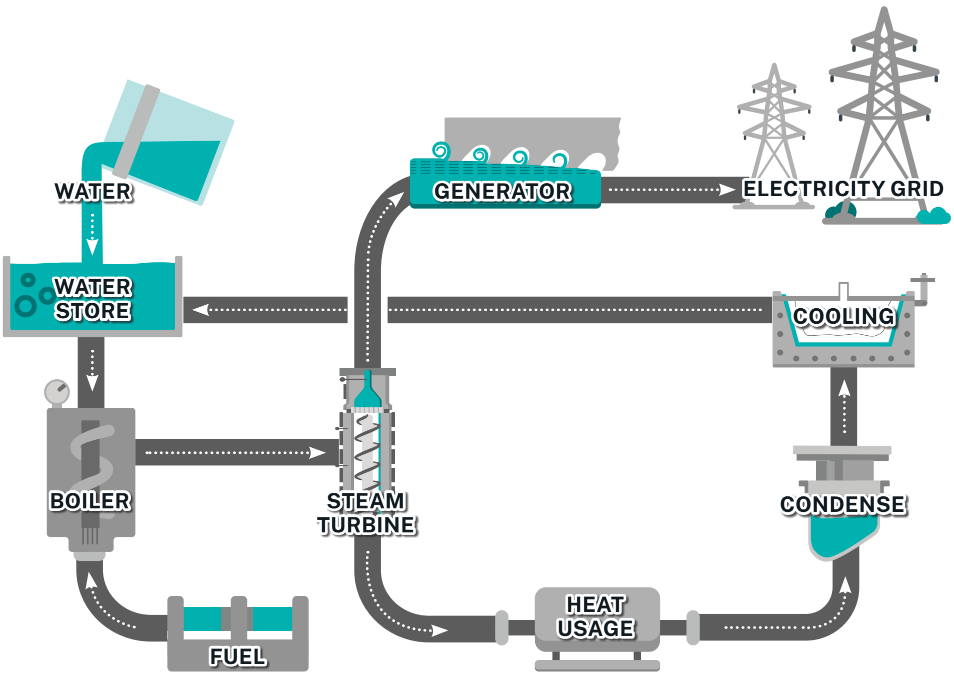
CO-GENERATION HEAT AND POWER SYSTEM AND EXAMPLE EQUIPMENT SPECIFICATIONS

Boiler:

12 TPH, **45** bar (g), **440** deg. C, traveling grate suitable for burning 100% de-oiled cashew nut shell

Steam Turbo Generator:

1500 KW installed capacity, with inlet steam conditions of **44** bar (g) and **435** deg. C with single bleed for delivering maximum **4** TPH of LP steam at **5** bar (a), **220** deg. C for process and deaerator



We envision a circular business model: constructing a CHP plant owned by a cashew kernel processor (ideally with CNSL extraction capabilities), and in close proximity to the processing factory. Shells generated during kernel processing (and turned into de-oiled shell cake after CNSL extraction) would serve as biofuel for the CHP plant, which in turn would generate electricity and steam needed for kernel processing. A CHP plant could thus provide an attractive alternative to the current method of sourcing unreliable and costly energy from the grid. Such a system is well-suited to cover not only the energy needs of a kernel processor, but also its thermal needs. CHP systems are best suited to factories that require large volumes of both energy and heat, and where heat can be consumed in close proximity to the plant. Cashew kernel processors fit this archetype: they require electricity to power the machinery, and steam for pre-heating raw cashew nut and use in some drying system.

The benefits of a CHP plant extend beyond the kernel processor operating the plant. In our models, a CHP plant could not only cover the steam and electricity needs of a single kernel processor, but also generate surplus energy that could be sold to the grid. For example, our model considered a cashew kernel processor with planned processing capacity of 18K MT of RCN, which requires ~8M units of energy annually. A 1.5MW CHP plant would generate ~9.5-10M units of energy (after auxiliary consumption), thus covering the entirety of the processing factory's energy needs and generating 1.5-2M surplus units, which could be sold back to the grid. Selling surplus energy back to the grid would not only benefit processors through generating incremental profit, but also benefit communities by providing a green source of energy.

E. **Cashew Shells:** From Cost to Profit

Using shells to fuel a CHP plant would turn shells from an economic burden to an economic opportunity for processors.

There are two levels on which this system would improve African kernel processor profitability and competitiveness. First, a CHP plant would improve processor competitiveness by providing a market for shells (currently disposed of at a cost to processors). CHP plants with capacity to generate 0.5-3 MW of energy require between 12-25K MT of de-oiled shells annually – meaning a plant would not be able to cover its supply needs from its own kernel processing facility alone, but would need to source shells from other processors. In this model, rather than paying to dispose of shells, processors would generate incremental profit from selling shells (estimated at ~$30 USD per MT of shell, or ~9x the cost currently paid by processors in Cote d'Ivoire to dispose of shells).

Second, additional economic benefits would be enjoyed by the kernel processor that owns and uses the steam and electricity generated by the CHP plant. By sourcing energy from on-site facilities, processors would avoid disruption caused by grid outages and fluctuations, and save on high costs currently paid for power from the grid and back-up generators. Reliable energy from a CHP system thus generates efficiency gains, thereby increasing processor kernel capacity and competitiveness. Moreover, by re-capturing steam used in the electricity generation system, a CHP plant negates the energy costs used to burn small volumes of shell for cashew kernel processing.

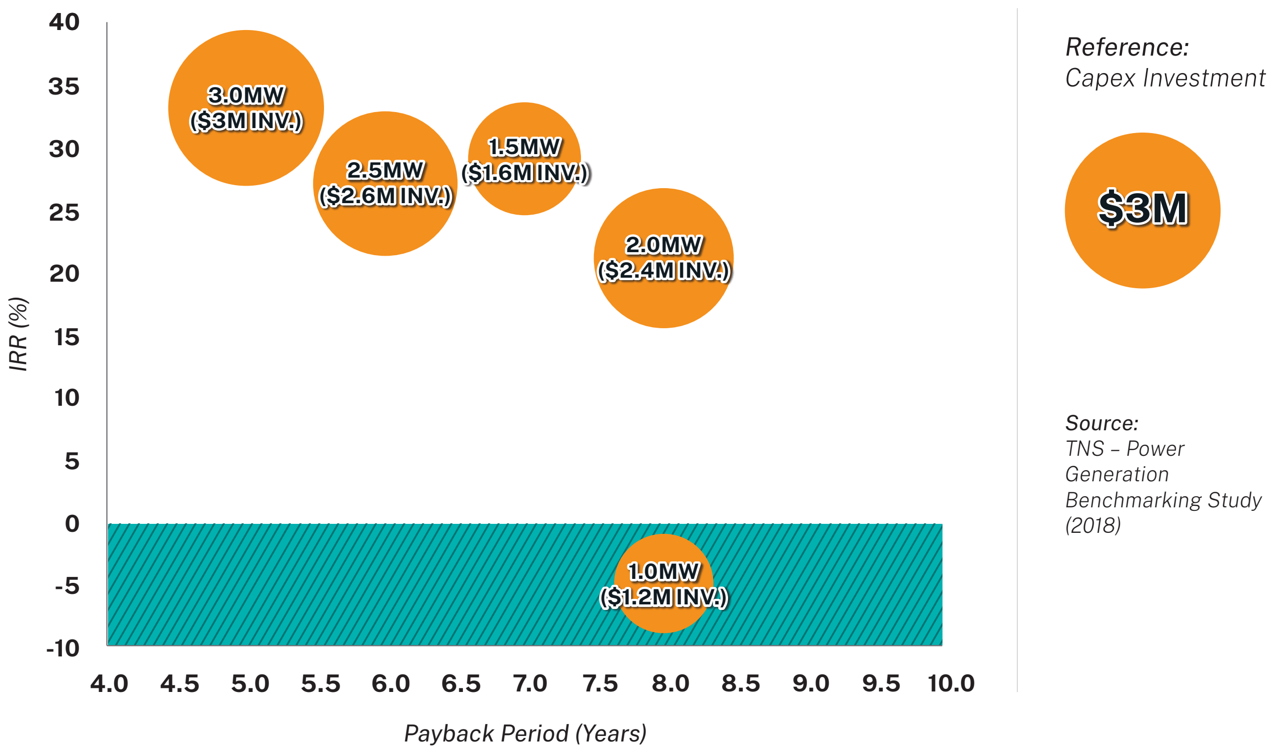
F. **Cashew Shells:** From Environmental Burden to a Model of Green Growth

Valorizing shells for energy generation does not only negate the adverse environmental effects of current shell disposal methods, but also goes one step further and creates environmental benefits. The benefits are two–fold: first, this system reduces the environmental footprint of dumping and open burning of shells for all processors that supply to the CHP plant. Second, for the processor that owns the CHP plant, using energy from cashew shells (a biofuel) rather than sourcing from fossil fuel power plants, reduces greenhouse gas emissions. Our analysis suggests that a CHP system would result in 50% reduction in greenhouse gas emissions.

OUR MODEL PRESENTS A LUCRATIVE BUSINESS OPPORTUNITY

While many existing initiatives to generate energy from cashew shell are largely reliant on subsidies, our model provides a strong business case. A cashew shell CHP plant is a lucrative investment opportunity with high IRR and a reasonable payback period. As part of the benchmarking study, TechnoServe drafted detailed financials for plants with power generation capacities of 0.5-3 MW. The findings show that CHP plants of 1.5-3 MW capacity are attractive investments. We evaluated profitability in 8 countries (Benin, Burkina Faso, Cote d'Ivoire, Ghana, Guinea-Bissau, Mozambique, Nigeria, and Senegal), and found that in each geography, plants of 1.5 MW and greater capacity generate meaningful net profit within the first year. Currently, TechnoServe is working to capacitate a kernel processor in Benin with a 1.5 MW CHP system.

IRR AND PAYBACK PERIOD FOR CHP PLANTS OF 1.0-3.0 MW CAPACITY



Source:
TNS – Power Generation Benchmarking Study (2018)

POTENTIAL FOR SCALE ECONOMIC AND ENVIRONMENTAL IMPACT ACROSS THE REGION

The regional impact of cashew shell heat and power plants is profound. In our analysis, many African countries currently have critical mass of shell available to support at least one cashew shell steam and electricity power plant. African kernel processing is gaining momentum and cashew shell utilization will add much needed economic competitiveness to the cashew industry and environmental benefits. This technology will have major impact on the following:

GREEN GROWTH MODEL:

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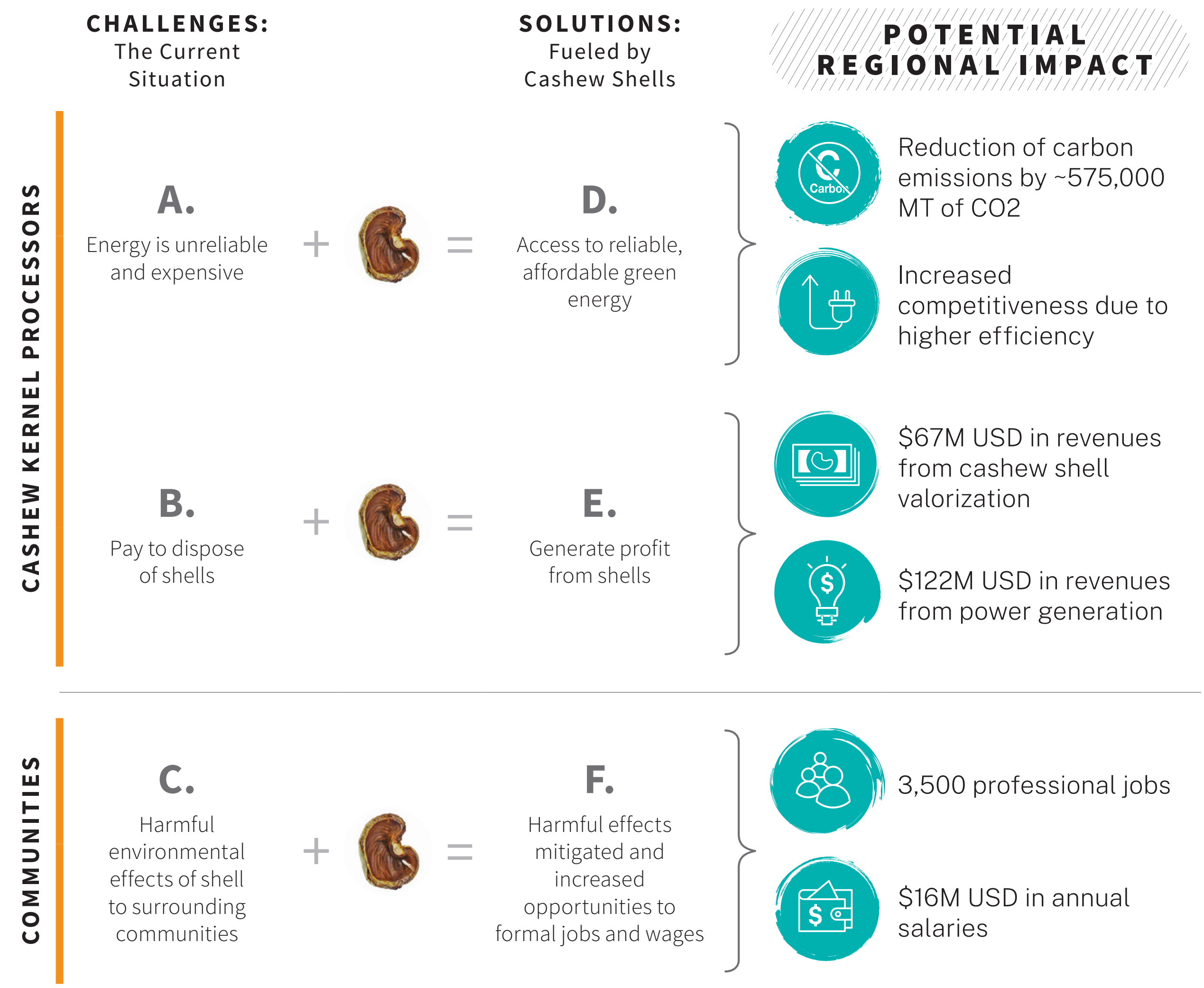

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